Did prehistoric foragers behave in an economically irrational manner? Raw material availability and technological organisation at the early Gravettian site of Willendorf II (Austria)

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Abstract

Willendorf II provides the longest and best-studied MIS 3 sequence in the Middle Danube region, and represents one of the key reference sequences for this time period in Central Europe. The assemblage chosen for analysis derives from archaeological horizon (AH) 5, attributed to the period of the first Gravettian between 30 and 27 ka uncal. BP. While previous analyses were all based on a selected inventory (mainly tools and cores) derived from the 1908/1909 excavations, the discovery of labelled wooden boxes containing numerous additional artefacts from the 1908/1909 excavations at the end of the 1990´s in the cellar of the Natural History Museum in Vienna considerably raises the total number of finds for all archaeological horizons, and opens new perspectives for investigating Upper Palaeolithic behavioural variability in the Middle Danube region. For the first time, the total assemblage of AH 5 has been analysed. Moreover, for the first time all artefacts have been assigned to a raw material source area, allowing for quantified observations on raw material economy and technological variability in the early Gravettian of the Middle Danube region. Willendorf II provides an excellent basis for the study of Gravettian lithic assemblage variability due to the wide array of local and nonlocal lithic resources available at varying distances from the settlement. We discuss the results in the light of the concepts of "technological provisioning" developed by S.L. Kuhn (1992), as it turns out that distance to source alone is not suitable to predict and explain raw material frequencies and the character of transported technologies on nonlocal material at Willendorf II-AH5. We argue that other factors such as the degree of anticipation of foreseeable activities and occupation span might account for the observed economic patterns. Our results clearly have broader relevance for understanding assemblage variability in the Gravettian of Central Europe and further afield.

1. Introduction

In European Upper Palaeolithic research, issues of culture history - questions of chrono-cultural grouping and technological lineages - are preeminent. Accordingly, variability in assemblage composition is typically seen as having cultural and/or chronological significance (see Clark, 2009). The formal variability of Gravettian industries is a case where variation in lithic technological systems is considered to reflect cultural traditions to a far greater degree than it reflects trade-offs to be assessed through economic models.

In studies of Gravettian lithic variability, culture-historical causes have received considerable attention (e.g. Djindjian and Bosselin, 1994; Klaric, 2007; Otte & Noiret, 2007; Svoboda, 2007; Moreau, 2010, 2011; Pesesse, 2010; Anghelinu et al., 2012; Ríos-Garaizar et al., 2012; Djindjian, 2013; Wierer, 2013; Marreiros et al., 2015; Polanská & Hromadová, 2015). This is partly imputable to the definition and routine practice of the *chaîne opératoire* as an analytical tool (Pelegrin et al., 1988), and related with it, the underlying claim of reading the enculturated minds of prehistoric knappers (Audouze, 1999; Bar-Yosef & Van Peer, 2009). Quantitatively underpinned economic explanations for observed patterns in Gravettian technological variation have been less systematically examined (e.g. Montet-White, 1988; Svoboda, 1994; Arrizabalaga et al., 2014; Lengyel, 2015). However, it is easier to attempt demonstrating the inadequacy of economic models first, than to demonstrate *a priori* that historically contingent cultural constructions and biases are not the driving motivations for past behaviours (Kuhn, 2004a: 563).

In an effort to overcome some of the shortcomings in the way variability of Gravettian industries has been approached, we use lithic artifacts from archaeological horizon (AH) 5 at Willendorf II, Austria, to investigate the interaction between raw material availability and technological organisation in the early Gravettian of the Middle Danube region. Willendorf II provides an excellent basis for the study of Gravettian lithic assemblage variability due to the wide array of local and nonlocal lithic resources available at varying distances from the settlement.

By addressing the issue of raw material economy at the onset of the Gravettian this paper examines the influences of differential raw material availability on raw material frequencies, patterns of blank selection, and lithic transport. Particularly, we address lithic assemblage characteristics in the light of the following questions:

- What are the frequencies of local vs. nonlocal raw materials in the early Gravettian assemblage?
- In which stage of manufacture (reduction) were specific raw materials introduced into the sites?
- Are there differences in terms of core and tool reduction intensity between raw materials from local sources compared to those from further away?

We discuss the results in the light of the concepts of “technological provisioning” developed by S.L. Kuhn (1992). We argue that distance to source alone is not suitable to predict and explain raw material frequencies and the character of transported technologies on nonlocal material at Willendorf II-AH5. Instead of concluding that early Gravettian foragers behaved in an economically irrational manner we argue that other factors such as anticipation of foreseeable activities and occupation span might account for the observed economic patterns.

2. Background

In Europe, the period between 36,000 and 30,000 calendar years ago witnessed a deep socio-economic change in human evolutionary history, which roughly coincides with the cultural change from the Aurignacian to the Gravettian technocomplex. Important new features of the period are the earliest unambiguous Upper Palaeolithic burials in Europe and the appearance of vast, intensively used open-air sites attesting patterns of increased residential stability (Soffer, 1989; Svoboda et al., 1996, 2000). It is generally agreed that the presence of such sites, interpreted as semi-permanent residential camps, is critical for the differentiation between Aurignacian and Gravettian land use strategies (Soffer, 1989; Svoboda et al., 1996, 2000). At the same time, Gravettian human remains reflect habitual burden-carrying and high levels of mobility, as is indicated by lower limb skeletal hypertrophy and proportionally long limbs relative to trunk length compared to recent (and more sedentary) Holocene human populations (Holt, 2003). Thus, Gravettian foragers seemed to have adopted a behaviour combining high levels of mobility and seasonal semi-sedentism (Trinkaus, 2005). The alleged high degree of mobility in the Gravettian has been interpreted as the result of climatic fluctuations and deterioration leading towards the Last Glacial Maximum, which may have triggered greater mobility and more extended social networks than among previous hunter-gatherer societies and hominin populations (Gamble, 1999; Svoboda et al., 2000). However, given the lack of post-cranial human remains for the previous Aurignacian (Bailey et al., 2009), the question as to what degree Gravettian foragers were actually more mobile than their Aurignacian counterparts remains difficult to assess from a physical anthropological perspective.

A significant behavioural shift occurring within this time period concerns the organization of lithic raw material economies in concert with variable blank production objectives and modalities (Floss, 1994; Féblot-Augustins, 1997, 2009; Miller & Straus, 2001; Moreau, 2009, 2010, 2012). While Late Pleistocene hunter-gatherers of both the Aurignacian and the

Gravettian deployed provisioning strategies according to anticipated future needs, it is generally taken for granted that the lithic technology of the Gravettian placed higher constraints on the quality of raw materials, thus justifying higher costs of obtaining lithic raw materials when the local stone proved unsatisfactory (Svoboda et al., 1996; Féblot-Augustins, 1997, 2009).

3. Materials and methods

3.1 Site and dataset

In Central Europe, assemblages attributed to the (late) Aurignacian and (early) Gravettian based on a secure chronostratigraphical context are scarce. Willendorf II represents one of the rare suitable sites with a series of stratified archaeological horizons from both techno-complexes. The Willendorf site cluster (eight sites: Willendorf I, Willendorf I-Nord, Willendorf II to VII) is located approximately 80 km west of Vienna in the so-called Wachau, a ca. 30 km long, narrow part of the Danube valley cut deep into the geological formation of the Bohemian Massif (Fig. 1). Willendorf II (48° 19′ 23.50” N, 15° 24′ 15.20” E) is the only systematically excavated site of the Willendorf site cluster. It represents an open-air site situated on the western side of the valley about 15 m above the river (230 m a.s.l.). J. Szombathy, H. Obermaier, and J. Bayer from the Natural History Museum in Vienna conducted initial excavations between 1908 and 1926. The hallmark of these excavations is the discovery of the famous Gravettian Venus figurine from below AH 9 (Antl-Weiser, 2008). In 1955, F. Felgenhauer further excavated the northern part of the site (Felgenhauer, 1956-1959). In 1981 and 1993, P. Haesaerts, F. Damblon and colleagues conducted geological and chronostratigraphic research on a newly opened section (Haesaerts 1990; Haesaerts et al.

1996; see also Nigst & Haesaerts, 2012; Nigst, 2012). From 2005 to 2011, excavations lead by P. Nigst, B. Viola and G. Trnka aimed at providing new data on the timing and nature of the Middle to Upper Palaeolithic replacement in the Middle Danube region (Nigst et al., 2008; Nigst et al., 2014).

INSERT FIG. 1 HERE

Willendorf II provides the longest and best-studied MIS 3 sequence in the Middle Danube region, and represents one of the key reference sequences for this time period in Central Europe (Haesaerts et al. 2007; Nigst & Haesaerts, 2012; Nigst et al., 2014). The deposits at Willendorf II cover a timespan of 45 to 23 ka uncal. BP, with a long sequence of occupation phases related respectively to the Szeletian, Aurignacian, and Gravettian (Felgenhauer, 1956-1959; Moreau, 2012; Nigst, 2012). In detail, the archaeological sequence contains 11 archaeological horizons (AH) (*Kulturschichten*): from bottom to top one AH (AH 1) without specified techno-typological attribution due to the low number of finds, one Szeletian AH (AH 2), two early (AH 3, 3ab) and two evolved Aurignacian AHs (AH 4, 4a), and six Gravettian AHs (AH 5-8, 8a and 9) (Nigst et al., 2014). The lithic assemblage studied here derives from AH 5, which has been attributed to the early Gravettian based on its chronostratigraphic position (Haesaerts et al., 1996; see also Nigst et al., 2014 for an update on the chronostratigraphic position) and lithic analyses (Broglio & Laplace, 1966; Kozłowski, 1986; Otte, 1981, 1991; Moreau, 2009, 2012).

AH 5 occurs in the geological Unit C, which records a complex set of greyish to yellowish loesses and pedological horizons. According to the old excavations (from which the material studied here originates) AH 5 occurs in the uppermost humic horizon of Unit C, a well-developed para-redzina (subunit C2). Charcoal from subunit C2 was dated to 30.5 ka uncal. BP (Haesaerts et al., 1996; Nigst et al., 2014).

Until recently, lithic studies on Willendorf II were based on the old inventory derived from the 1908/1909 excavations, with only small amounts from the excavations of 1912, 1913, 1926, 1927 and 1955 (Felgenhauer, 1956-1959; Broglio & Laplace, 1966; Hahn, 1977; Otte, 1981, 1991; Kozłowski, 1986; Teyssandier, 2007; Moreau, 2012). Several labelled wooden transport boxes containing numerous lithic artefacts from the 1908/1909 excavations were stored in the cellar of the Natural History Museum (NHM) in Vienna since the original excavations, but only opened from 2005 onwards (Nigst, 2004). The materials in these boxes considerably raised the total number of items for all archaeological horizons (Nigst, 2004, 2006, 2012), and opened new perspectives for investigating early Upper Palaeolithic, Aurignacian and Gravettian behavioural variability in the Middle Danube region. The wooden box of AH 5 was opened in May 2008 by two of us (L.M. and P.R.N.) with the permission of W. Antl-Weiser and A. Kern (Department of Prehistory, NHM Vienna) (Fig. 2). The box mainly contained unretouched blanks, shatter from core reduction, and a few volumetric cores and manuports. Since 2008, all artefacts from the wooden box of AH 5 have been inventoried and individually recorded by one of us (L.M.) using an attribute recording system according to a series of metric, typological and technological attributes building upon existing analytical frameworks and attribute systems (e.g. Pelegrin et al., 1988; Auffermann et al., 1990; Geneste, 1991; Cattin, 2000; Pelegrin, 2000; Simon & Moreau, 2012).

INSERT FIG. 2 HERE

The artefacts from the wooden box have never before been studied, hence this study provides for the first time a comprehensive overview of the complete lithic assemblage from the early

Gravettian AH 5. Prior to this study, little was known about the provenance of the raw materials represented in the early Gravettian AH 5 assemblage and whether they derived from local or nonlocal sources. Here we present qualitative and quantitative data on raw material availability and use for the first time. The approach adopted here to explain assemblage variability draws on the concept of "technological organisation" developed by North American researchers interested in assemblage characteristics as a consequence of adaptive problem solving (e.g., Nelson, 1991; Marks et al., 1991; Kuhn, 1992, 1995, 2004b; Andrefsky, 1994; Roth and Dibble, 1998; Blades, 1999; Beck, 2008).

3.2 Raw material sources

To address the aspect of raw material availability on lithic assemblage characteristics, we assume that using the present-day landscape with its raw material occurrences as a proxy for the Gravettian landscape is justifiable. There have certainly been periods of erosion and loess infilling of various areas in the Middle Danube region. However, the overall topography of the region has remained broadly unchanged for thousands of years. Geologically, the eastern part of Central Europe is characterised by several major geological units: Eastern Alps, Bohemian Massif, Western Carpathians, Sudetes Mountains, Pannonian Basin, some of which are shown in Figure 1.

Eleven separate raw material classes have been determined based on visually characteristic properties such as colour, fossil inclusions, cortex, quality (i.e., granularity) and texture (i.e., homogeneity). Raw material identification was backed up by two reference collections. The first collection consists of a sample of local raw materials collected in the Danube river gravels in March 2012 by two of us (M.B. and L.M.). For the nonlocal materials, we used the raw material comparison collection ('Lithothek') of the Department of Prehistoric and

Historic Archaeology, University of Vienna (G. Trnka), as reference collection. Microscopic identification by means of a binocular microscope using 20 to 70-fold magnification was used to a limited extent for questionable artefacts.

Local silicites

Gravels from the nearby Danube riverbed represent the main source of siliceous raw materials, including Northern Alpine Chert (*Jurahornstein*), radiolarite, silicified limestone, spiculite, spongiolite, quartz and quartzite. Given the difficulty of accurately discriminating some of the aforementioned raw material types macroscopically, we grouped all local varieties together for this study. The primary source area, the Northern Calcareous Alps, is indicated in the map (Fig. 1).

Since radiolarite can be collected from the river gravels in the vicinity of the site, we consider the Danube riverbed to be the most probable source of radiolarite used at Willendorf II. Accordingly, all artefacts made of radiolarite have been recorded as to be of local origin. However, other potential radiolarite outcrops occur within the St. Veit Klippen Belt with Mauer near Vienna as the best documented source location (Trnka, 2014), as well as in Mesozoic sediments of the White Carpathians in the Moravian-Slovakian borderland to the East (Brandl et al., 2014 and references therein). Future work will have to explore the possibility of long-distance transport of nonlocal Carpathian radiolarite into the site by means of geochemical analyses. The validity of LA-ICP-MS data with radiolarite and compositional data analysis has been demonstrated recently by revealing geochemical fingerprints of discrete geological formations occurring across the Northern Alps and the Carpathians (Brandl et al., 2014).

Nonlocal silicites

Widely used throughout the archaeological literature, the term flint was interchangeably applied to a variety of SiO_2 raw materials (Brandl, 2013-2014). In the context of the Middle Danube region, the term flint refers to erratic siliceous rocks derived from moraine sediments of the Elster and Saale glaciations transported as far south as the Moravian Gate (Fig. 1). The source of erratic flint closest to Willendorf II broadly corresponds to the Moravian Gate area, at least 230 km from Willendorf II (Fig. 1). In the Moravian Gate area flint occurs in redeposited contexts. While primary outcrops of Jurassic "flint" in Silesia (i.e., Craców-Czestochowa "flint") are frequently of high quality and variable size range (Přichystal, 1991, 2013), flint nodules derived from moraine sediments are usually small in size and occur often in rather low frequencies (about 0.3 to 3.1%) (Svoboda, 1994: 71). Since macroscopic distinction of various flint types/sources is difficult and highly prone to errors due to similar appearance (Svoboda, 1994), particularly in the case of silicite varieties displaying surface alteration (i.e., patination) (Brandl, 2013-2014), in this paper all flint artefacts have been assigned to the erratic flint variety (Table 1).

INSERT TABLE 1 HERE

Moravian Jurassic cherts (MJC) subsume all possible sources of cherts originally coming from Jurassic sedimentary rocks in Moravia (Přichystal, 2010, 2013). MJC occur in gravels of the Lower Cretaceous and Cenozoic (Tertiary and Quaternary) age. The four presently known Jurassic limestone exposures (Fig. 1) comprise three outcrops in the surroundings of Brno (i.e., Krumlovský les, Stránská skála, and Bořitov chert types) and one outcrop located in the central part of the Moravian Karst, east of Brno (i.e., Olomučany chert type) (Přichystal, 2010, 2013). However, relics of Jurassic sediments can also be found in southern and southwest

Moravia in Lower Cretaceous to Quaternary gravels (Přichystal, 2013; Brandl et al., 2015). While different varieties of MJC including Krumlovský les and Stránská skála types have been observed at Willendorf II-AH 5 (L.M. and M.B. personal observation), they have not been individually quantified for this study (Table 1).

Additional categories “flint or chert” and “chert undetermined” have been created given the large variability of flint and chert in the assemblage, hence the difficulty to always distinguishing MJC from flint, or MJC from local varieties of fine-grained chert based on visual observations, particularly in the case of small and/or patinated pieces (Table 1).

Chalcedony and jasper artefacts are likely to originate from the north of Lower Austria (Fig. 1). These SiO_2 varieties represent products of intense weathering of predominantly ultrabasic rocks (serpentinites) (Mateiciucová 2008; Přichystal 2010). The nearest present-day outcrops occur at a distance of 15-20 km from Willendorf II (Table 1).

4. Results

4.1 Patterns of raw material procurement

At Willendorf II, AH 5 has been excavated over ca. 200 m^2 although most objects have been found in the southern part of this area (Felgenhauer, 1956-1959). The assemblage consists of 2952 lithic artefacts exceeding 1.0 cm in size, including 59 volumetric cores and 7 tested blocs. Nearly three fourth of the assemblage (i.e., 2177 objects) originate from the wooden box. Additionally, the wooden box yielded 6 probable hammerstones on sandstone and 12 manuports. The latter consist in river pebbles of various sizes and weights ranging between

4.7 g and 3329.0 g, on quartzite, sandstone, silicified limestone, amphibolite, and serpentinite. At least three of them bear scars indicative of their use as retoucher, hammer or anvil.

Most of the artefacts (66.6%) are made from locally available materials collected from the Danube gravels (Table 1). However, a significant amount of nonlocal material (32.5%) was transported into the site as well. Below, we compare local and nonlocal materials in order to examine the influences of raw material availability on lithic technology, typology, and raw material procurement and transport strategies.

4.2 Patterns of blank selection

Core reduction was oriented towards the production of blades and bladelets following a continuum of blades/small blades and bladelets within the same core reduction sequence by making use of both direct soft stone percussion and organic percussion (Moreau, 2012). Blades and bladelets derive mainly from the unipolar reduction of volumetric prismatic cores. An autonomous bladelet production on burin-cores, and on the narrow side of thick preparation flakes and frost shards has been demonstrated as well. For more details on the main technological features characterising the assemblage of Willendorf II-AH 5 see Moreau (2009, 2012).

In all raw material classes, modified blanks (i.e., tools) were mainly manufactured on blades, followed by bladelets when these are present (Table 2). Given the absence of sieving in the course of the 1908 to 1955 excavations, bladelets are likely to be underrepresented in the assemblage. Nevertheless, the significant amount of retouched bladelets and, to a lesser degree, burin spalls, clearly suggest a careful excavation strategy, which consisted in scraping away the sediment of the archaeological horizons by means of knives, so-called *Grabungsmesser* (Antl-Weiser, 2008; Nigst, 2012: 79).

INSERT TABLE 2 HERE

At Willendorf II-AH 5, blades represent the most common blank type used for tool manufacture. To determine the specific criteria used to select blades for tool production we compared the modified blades to the unretouched blade blanks between local and nonlocal materials (Table 3). An analysis of dimensional variability shows that blade tools are wider and thicker than unretouched blade blanks for each raw material category (Local-width: Mann-Whitney U test, $Z=-4.50648$, $p<0.0001$, Local-thickness: Mann-Whitney U test, $Z=-3.00975$, $p=0.0026$; MJC-width: Mann-Whitney U test, $Z=-3.90229$, $p<0.0001$, MJC-thickness: Mann-Whitney U test, $Z=-3.70574$, $p=0.0002$: Flint-width: Mann-Whitney U test, $Z=-5.2102$, $p<0.0001$, Flint-thickness: Mann-Whitney U test, $Z=-4.84427$, $p<0.0001$) as well as for the entire sample (Width: Mann-Whitney U test, $Z=-7.6209$, $p<0.0001$; Thickness: Mann-Whitney U test, $Z=-5.63883$, $p<0.0001$). This difference is apparent, even though the retouched pieces have partly lost some of their original width due to retouching. Thus, retouched blades tend to be the larger blade blanks (Fig. 3). Comparable patterns were demonstrated for other Early and Mid Upper Palaeolithic contexts (e.g., Montet-White, 1988; Blades, 1999; Moreau et al., 2013). Length has not been taken into consideration here given the relatively high degree of fragmentation of blade tools, hence lack of sample representativeness.

INSERT TABLE 3 HERE

INSERT FIG. 3 HERE

Despite varying distances from the lithic source, nonlocal tools have similarly sized blanks as local tools (Table 3). However, the dimensional variability of tools made of nonlocal materials, as measured by the coefficient of variation (C.V.), is in every case less than the variability of local tools. This implies that imported blanks selected for transport were more restricted in size and may reflect a more restricted range of acceptable dimensions (Roth & Dibble, 1998).

Toolkit diversity

At Willendorf II-AH 5, tools (i.e., retouched blanks) account for 10.3% of the total lithic assemblage (Table 4). From the 303 tools in the assemblage, only 20 specimens originate from the wooden box. Uni- and bilaterally retouched blades (23.1%) dominate the assemblage followed by backed pieces (20.5%), comprising mainly Gravette and Microgravette points, as well as backed bladelets. A common characteristic for Gravettian assemblages is that burins (14.7 %) are more frequent than endscrapers (10.2%).

INSERT TABLE 4 HERE

Tools on flint are almost twice as numerous as tools on local materials (Table 2). In order to evaluate whether tools of different raw materials were used for different tasks, we assess toolkit diversity between local materials and nonlocal flint, assuming that tool types and tasks were somehow related. Here, toolkit diversity has been gauged by using the ecologically derived measures of richness, evenness, and heterogeneity (Bobrowsky & Ball, 1989; Beck, 2008). The measurement of richness used here corresponds to the number of tool types present in each raw material class. We compare the toolkits using two typological lists: one detailed list of 32 tool types (Table 4), most of which derive from the typological classification system of Sonneville-Bordes and Perrot (1954, 1955, 1956a, 1956b); another simplified list comprising only 12 morphological types: lateral retouch, truncation, pointed blank, borer, backed piece, backed discard, *fléchette*, burin, endscraper, scraper, combination tool, and splintered piece. The measure of evenness estimates deviation from an even assemblage by quantifying the distribution of specimens across tool types for each assemblage (Beck, 2008). A value of 1 means all types are equally represented, while lower estimated variance indicates greater assemblage diversity. Finally, heterogeneity measures both the number of types present and the distribution of those types in each assemblage with a single statistic (Beck, 2008: 770). High heterogeneity values indicate increased diversity.

The different measures of toolkit diversity between local materials and flint have been summarised in Table 5. While not excluding the possibility that differences in tool type richness between both raw material groups is a factor of sample size (Kintigh, 1989), it is apparent that with reduced numbers of tool types, differences in evenness and heterogeneity tend to increase (Table 5). While the flint toolkit exhibits the highest richness, differences in evenness (df=1; F ratio=0.55; $p<0.836$) and heterogeneity (df=1; F ratio=0.208; $p<0.693$) between local materials and flint are not significant. Thus, the association between raw material categories and tool types is not very strong, as both local and nonlocal assemblages exhibit a similar overall typological composition characterised by a fairly high degree of typological diversity. This strongly suggests that early Gravettian foragers at Willendorf II-AH 5 were apparently not actively selecting different materials for different tasks.

INSERT TABLE 5 HERE

The observed pattern is somewhat counterintuitive, as one would expect stone tool morphological variability and toolkit diversity to be related to the availability and quality of stone tool raw materials (Andrefsky, 1994). In the context of the Middle Danube region, both local raw materials and nonlocal flint represent cryptocrystalline rocks. However, local North Alpine raw materials, particularly radiolarite, chert and silicified limestone, exhibit a fairly large range of internal heterogeneity in terms of granularity and frequency of raw material impurities, such as natural cleavage planes, that would interfere with the direction of applied force. Moreover, the rate of occurrence of local raw materials suitable for tool production must have been fairly low based on present-day observations. Only some cobbles of the same general raw material class in the Danube riverbed have a finer grain and degree of homogeneity than the rest of that class. On the contrary, flint is more homogeneous and, accordingly, of better quality, resulting in more controlled, thus efficient, core reduction and tool production (Přichystal, 2013). Despite these differences in quality and availability, indices of typological diversity indicate that nonlocal flint has been treated in a similar way like the locally available stone tool raw materials.

4.3 Patterns of lithic transport

To further assess lithic assemblage variability at Willendorf II-AH 5 we investigate reduction intensity-raw material distance relationships by looking at the represented reduction stages for different raw material classes and different measures of intensity of raw material use. Most of the lithic assemblage recovered at the site was made of local materials derived from the riverbed of the Danube, followed by nonlocal material (Table 1). The main differences in the effects of lithic raw material availability on the organisation of technology and the use of local and nonlocal raw materials are apparent in the technological categories (Table 6) and the frequency of dorsal cortex on debitage blanks (Table 7). Sites with access to locally accessible, good quality raw material sources often show a greater emphasis on primary raw material exploitation (Roth & Dibble, 1998). This is the case at Willendorf II-AH 5 where local material is present in the form of tested cobbles, high proportions of cortical flakes, angular shatter, cores and core shatter, clearly indicating that primary core reduction took place on-site (Table 6). On the contrary, it is expected that nonlocal raw materials would be transported to sites in formal artifact shapes, and not as bulk raw material cobbles or chunks (Andrefsky, 1994). At Willendorf II-AH 5, the high percentage of tools made of flint (Table 6) strongly suggests that part of them were brought to the site as finished tools, as elements of transported toolkits used to provision individuals according to anticipated needs (Kuhn, 1992). Nevertheless, the presence of unretouched debitage blanks and prepared cores indicates that secondary core reduction of nonlocal materials took place at Willendorf II-AH 5 as well. Moreover, the presence of partially backed blanks among the toolkit on flint (Table 4) clearly indicates tool manufacture on nonlocal material on-site.

INSERT TABLE 6 HERE

INSERT TABLE 7 HERE

As core reduction increases, the number of blanks per core and the extent of core preparation increase while average core size, blank size, flake platform area and area covered by cortex decrease (Dibble et al., 1995). At Willendorf II-AH 5, increased exploitation of nonlocal material (including both MJC and flint) is reflected in the overall smaller size of unretouched laminar blanks regarding width (Mann-Whitney U test, $Z=-3.95607$, $p<0.0001$) and thickness (Mann-Whitney U test, $Z=-5.65554$, $p<0.0001$) compared to local material (Table 3). Moreover, average dorsal cortex cover of nonlocal blanks, and particularly the importance of blanks with decreased dorsal cortex cover (i.e. 1-30%) compared to the frequency of primary cortical flakes of local materials (Table 7) points to more intensive core reduction of nonlocal materials and suggests that initial reduction of these materials occurred elsewhere. The latter conclusion is supported by the significantly different distributions in dorsal cortex frequencies between local material and flint (Chi-square local/flint: $\chi2 = 97.5$, df = 3; $p<0.000$). Both MJC and flint were probably prepared in the field before transport and reduced further after they arrived at the site. The different average cortex cover distribution between these raw material classes is however different (Chi-square MJC/flint: $\chi2 = 9.4$, df = 3; $p<0.029$), suggesting differential core preparation and reduction between both raw materials.

At Willendorf II-AH 5, the effects of raw material reduction intensity, as measured by distance to source area, are further apparent in the measures of mean volume and weight between local and nonlocal materials (Table 8). As expected, with increasing distance from source mean core volume and weight decrease, although in a nonlinear relationship (Fig. 4 and 5). While sample size of nonlocal cores hampers statistical comparisons, the small-sized cores on jasper and chalcedony strongly suggest that even relatively minor differential distances from raw material sources (i.e. less than 20 km) can have a significant impact on raw material economy, as has been repeatedly observed in other contexts as well (e.g., Marks et al., 1991; Roth and Dibble, 1998; Kuhn, 2004b).

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INSERT FIG. 4 HERE

INSERT FIG. 5 HERE

With the exception of jasper, nonlocal materials show pronounced differences in blank to core ratios (Table 9), which represent one further measure to estimate the degree of core reduction (Roth and Dibble, 1998). Given that core reduction was primarily oriented towards production of blades and bladelets (Moreau, 2012), and in order to avoid bias with those finished tools brought in as transported “personal gear” (Binford, 1979), only unretouched laminar blanks have been considered in the blank to core ratio (Table 9).

INSERT TABLE 9 HERE

At Willendorf II-AH 5, the significantly higher frequency of retouched tools on flint compared to local materials is a further expression of the effect of source distance on reduction intensity (Table 6). However, the other nonlocal materials do not conform to this pattern. Most of all, nonlocal blade tools do not differ significantly in width (Mann-Whitney U test, $Z=-0.42028$, $p=0.6743$) and thickness (Mann-Whitney U test, $Z=-0.587058$, $p=0.5572$) from local blade tools (Table 3), despite an expected longer use-life for nonlocal mobile toolkits (Kelly, 1988; Kuhn, 1992, 1994). Moreover, no apparent difference has been observed in retouch intensity between local and nonlocal raw material classes, either in terms of retouch extent (i.e. the number of retouched blade edge segments), and retouch intensity (Blades, 1999). Partial edge modifications on blades are frequent (i.e. ca. 30%) in both local material and flint, and bilaterally retouched blades are even better represented in local raw materials (Table 4). The intensity of retouch for either local and nonlocal toolkits does not vary according to raw material source neither, as measured by the length of the few complete endscrapers on blade (N=7) between local and nonlocal materials. Despite higher frequencies of retouched flint tools, there seems to be no relationship between the intensity of tool use and transfer distances for the raw materials of which they were made. This conclusion is supported by the overall similar typological composition and diversity of local and nonlocal tools (Tables 4 and 5). Thus, transported flint tools seem to not represent exhausted items destined to be replaced upon arrival by readily available local raw materials. These observations suggest that the technological organisation at Willendorf II-AH 5 was driven by other factors than the constraints exerted by distance from raw material source alone.

Discussion

The overall increase in high-quality, more distant lithic raw materials is generally considered to be one of the hallmarks of the Central European Gravettian (Floss, 1994; Svoboda et al., 1996, 2000; Féblot-Augustins, 1997, 2009). This trend has been interpreted as reflecting the increased requirement on quality of lithic raw materials for the production of backed points from regular and standardised small blades and bladelets (e.g. O´Farrell, 2003; Moreau, 2009, 2012). However, the factors underlying the trend towards increased quantities of high-quality, nonlocal materials remain poorly understood and little investigated.

Many authors use the distance from site to source as a proxy for raw material cost and refer to distance-decay models to address lithic assemblage variation (e.g. Newman, 1994; but see Close, 1999). Distance-decay models stress a strong relationship between distance and assemblage variation and propose that as distance from raw material source increases, raw material processing and curation of stone tools increase, whereas artefact abundance decreases. At Willendorf II-AH 5, nonlocal materials which account for nearly one third of the lithic assemblage do clearly not conform to the distance-decay model. Particularly, the treatment of flint at Willendorf II-AH 5 illustrates the complex relationship between raw material provenience and intensity of raw material exploitation. Compared to locally available resources, flint tools seem to have been treated and discarded in similar conditions as local tools. Both flint and local tools show no significant difference in terms of typological composition and diversity, patterns of blank selection and reduction intensity. Moreover, secondary core reduction of nonlocal materials for tool production has taken place on-site. Accordingly, at Willendorf II-AH 5 stone tools made of flint do not conform to the expectations for continuously transported personal toolkits which should be used more extensively as a need to extend their utility (Kuhn, 1992, 1994), before being abandoned upon arrival at the site and replaced by locally available material.

In the absence of a straightforward relationship between distance to source and nonlocal raw material use, does this necessarily imply that early Gravettian foragers behave in an economically irrational manner? We do not think so (contra Tsonev, 2004). Instead, other factors than distance to raw material source should be taken into consideration to explain the character of transported technologies on nonlocal material at Willendorf II-AH 5. The concept of technological provisioning devised to predict variability in lithic assemblages is particularly pertinent for interpreting economic behaviour of prehistoric foragers to keep themselves supplied with stone tool raw material under different sets of constraints (Kuhn, 1992, 2004b). At Willendorf II-AH 5, flint and, to a lesser extent, MJC arrived in various states of manufacture as a result of "provisioning places". The latter implies that a ready supply of stone has been amassed in a given place according to foreseeable activities, thus relaxing need to squeeze the last bit of use out of every artifact (Kuhn, 2004b: 433). Extensive reduction and reworking of nonlocal tools in an effort to extend their utility beyond optimal use-life via resharpening is not attested at Willendorf II-AH 5. Along with the anticipation of activities, relative duration of occupation and the repeated use of the same place over time in the course of the annual foraging cycle might be decisive factors to explain the technological organisation observed at Willendorf II-AH 5. As occupation span increased, local raw materials in the form of river cobbles from the Danube riverbed, though of less predictable quality, was increasingly exploited to avoid raw material shortfall. Future work will explore the similarities and differences with the Aurignacian assemblages of Willendorf II and will take into account the possible influence of ecological variables on assemblage characteristics.

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